LUBRICATION

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General View of plant below the Falls. Latest units installed shown on the right. Notice smoothness of water compared with that coming from left part of building.

Lubrication of Hydraulic Turbines
Niagara Falls Power Company

IT HAS long been an axiom in power development that greater efficiency can be attained by the use of larger and more powerful units. Every unit, almost regardless of size, requires about the same number of auxiliaries to keep it in operation and also demands about the same amount of supervision in order to furnish proper assurance of continued and satisfactory performance. No matter how big a proposition appears, it is found on close analysis that its successful execution depends on the solution of some detail which at first may not seem particularly difficult or to necessitate much study. While a decrease in the number of units for equal power decreases the operation costs, and

large units can be constructed with greater mechanical and electrical efficiency than smaller units, yet to attain this result many details of construction and operation have demanded greater attention than in the small units. This is particularly true of the lubrication of power machinery. The transition from the ordinary grease cup or sight feed oiler, as used in small machines to the properly adjusted oiling system as found in large installations, has only been made after considerable study and experiment. Without an efficient lubrication system the modern turbo-generator, whether water or steam, would be a source of trouble instead of a pleasure to operate. This development of water power apparatus, and the successful solution of the attendant lubrication problems, is well exemplified at the plant of the Niagara Falls Power Company. Here we not only have some of the latest and largest types of hydro-electric generators ever manufactured, and so arranged that they can operate simultaneously on the same transmission line, but also we have an oiling system which reduces friction losses to such a small amount that they are negligible compared to the power developed.

In addition to the lubrication systems of these latest turbo-generator units, those of the other units are of considerable interest. Although these units themselves are smaller, the total power developed is greater and the lubrication systems are strictly modern and efficient for the different types of installations exemplified. We shall consider these installations in the order of their construction.

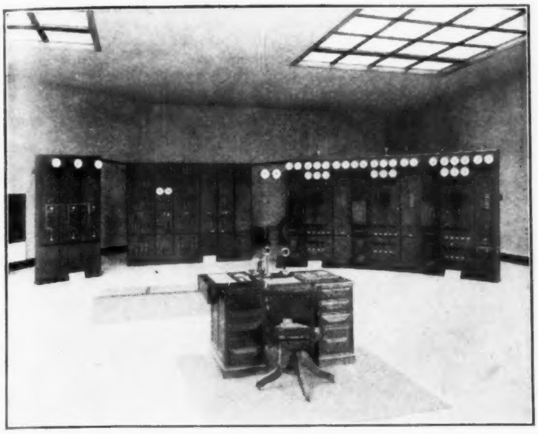
Upper Power Houses

In general, there are two hydraulic systems used in the development of the water power available at Niagara Falls into a form of energy capable of practical application to industries. The first system of any magnitude to be installed utilizes the water head available by taking the water from the river on the American side above the falls and dropping it vertically down a shaft hewn out of the rock at the bottom of which are installed the hydraulic turbines. The water is discharged through a long tunnel to a point about 2,000 feet below the American Falls where it flows into the river. The energy given to the turbines is transmitted by long vertical shafts directly connected to electric generators situated at the top of the penstock. There are two power houses operating under this hydraulic system. These, together, contain 21 sets, or units, each unit having a capacity of 5,500 H. P., and developing electric energy at 2,200 volts, 25 cycles, 2 phase. The exciters for the generators are operated by separate turbine units. The speed of each unit is controlled by a governor which automatically, with change in load, increases or decreases the gate openings to the turbine so as to maintain the speed, and hence the voltage constant. These governors operate with oil which is supplied at 250-pound pressure by means of a pump independent of the lubrication system. The oil, however, returns to the general oil sump.

The units in these power houses are lubricated by high pressure oil systems which differ slightly in the two plants. In power house No. 2 the 11 units are equipped with oil pressure thrust bearings. These consist of two discs situated directly beneath the generator; the top disc being fastened to the vertical driving shaft while the bottom disc is attached to the foundation, and hence is stationary. Each unit is fitted with a direct connected pump mounted on a 500-gallon tank which forces oil between the discs at a pressure of 85 pounds. The oil forced out by the bearing flows to a sump.

Besides the thrust bearings, there are guide bearings which maintain the units in proper alignment. These originally were babbitted bearings and were lubricated with oil by a gravity system. It was found, however, that the lower guide bearings were so placed that water was often sucked into them and became mixed with the oil. As the oil from these bearings was returned to the common sump, from which oil for the whole system was drawn, this water caused considerable trouble. Lignum Vitae bearings, lubricated by water, have therefore been substituted for the babbitted bearings.

In addition to the thrust and guide bearings there is a disc at the bottom of the shaft which



Control room in plant No. 3. One man can manipulate and tie together all the units from this point.

supports some of the weight of the unit by means of an hydraulic pressure on its underside.

The 10 units in power house No. 1 are constructed slightly different from those in power house No. 2 just described. The thrust bearings are a combination oil pressure and roller bearing. The governors and bearings of each unit are supplied with oil at 200 pounds pressure by an individual direct-connected pump, operating independently of the other units. The oil from all units, however, returns to a central filtering system and is pumped to a central storage reservoir.

As, in spite of all precautions, water may become mixed with oil the latter must be non-emulsifying and separate easily from water. A viscosity of 180 seconds, at 100° F. Saybolt universal, has been found sufficient to carry the load satisfactorily, both with the bearing and governors. The same oil can generally be used on auxiliaries, though with some particular types it may be necessary to have an oil of slightly higher viscosity.

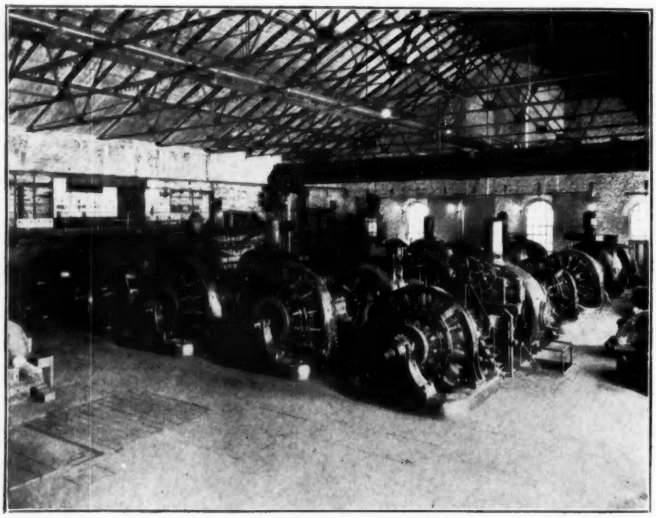
Lower Power Houses

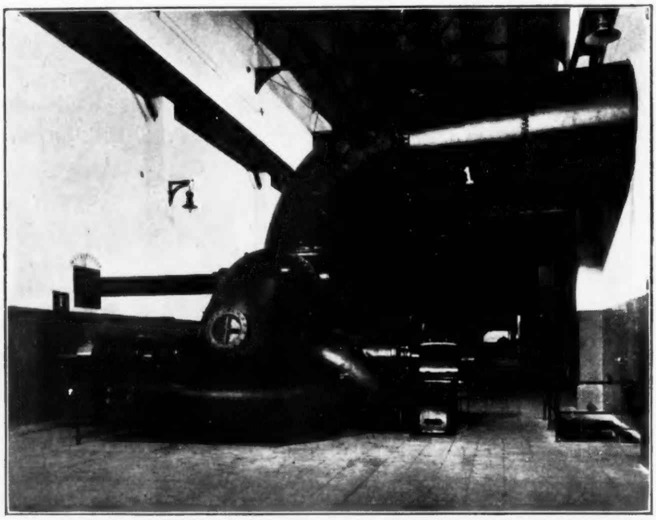
The hydraulic system just described is deficient in that it does not develop the full head available, utilizing only about 130 feet of the 220 feet difference in level between the river above and below the falls. The second system to be used more fully utilized this head by taking the water from above the falls into an open cut canal, which carries it to a point on the bank about 4,000 feet below the falls where it is dropped to the lower water level by means of an inclined tunnel or penstock. The turbines and electric generators are installed in compact units at the lower end of this penstock, and the water is discharged with practically no loss in head directly into the river below the falls. The first installation using the full head of water from the open canal was comparatively small, only about 6,000 H. P., and has since been abandoned. The system, however, has been expanded several times until now sufficient equipment is installed in the several power houses at the base of the cliff, that practically all the water which the treaty with Great Britain allows to be diverted from the Falls for power purposes can be utilized.

The second installation using water from the canal is capable of producing about 25,000 H. P., but now 15,000 H. P. only is used; the balance being for a reserve or for emergency. The third plant, however, developing about 130,000 H. P. in 13 units is worthy of notice as being strictly modern though not the latest word in turbo-generator construction. The units in this plant have generator and turbine direct connected on the same horizontal shaft, though the generator and turbine are in separate rooms. The water enters the turbine horizontally at the center of the rotating cage or runner, and discharges into a casing around its periphery from whence it flows directly into the river.

The generators to which these turbines are connected produce electric energy at 12,000 volts, 3 phase, 25 cycles, and operate at a speed of 300 R.P.M. The rotors weighing about 95,000 pounds each are supported on babbitted bearings 60 inches long with journals 16 inches in diameter. The bearings are lubricated by means of a ring resting on the top of the journal, and running in a bath of oil in the bearing support. The rotating part of the turbine is supported and lubricated in a similar manner except that precaution is taken in the design so that water does not work along the shaft into the bearing.

An oil of 350 seconds viscosity, at 100° F. Saybolt universal, has been found to operate satisfactorily in these bearings, but, as in spite of all precaution, water may become mixed with the oil, the latter should be so





View in Plant No. 2 situated above the Falls.

Turbine room in Plant No. 3, showing horizontal turbines. Water enters by means of large pipes overhead and discharges below the floor.

Generator room in Plant No. 3. Bearings carrying rotating part are ring oiled. Oil reservoir in base.

refined and of such a nature as to separate easily from water and not emulsify.

Latest Installation

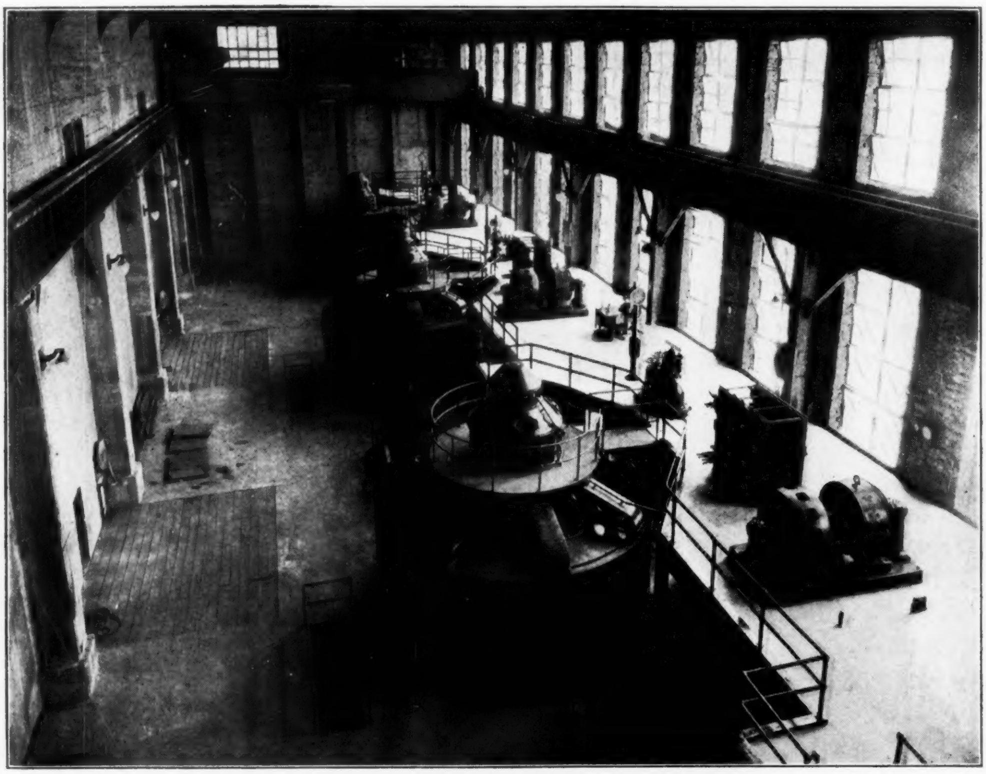
Due to the exigencies of the late war, it became advisable to develop to the limit the water power allowable at Niagara Falls for power purposes. It was determined to do this in as large units as practical, and in order to expedite this as much as possible the contemplated development was divided into three units and given to separate companies to construct. These units are now installed and operating satisfactorily and constitute the latest word in hydro-electric development.

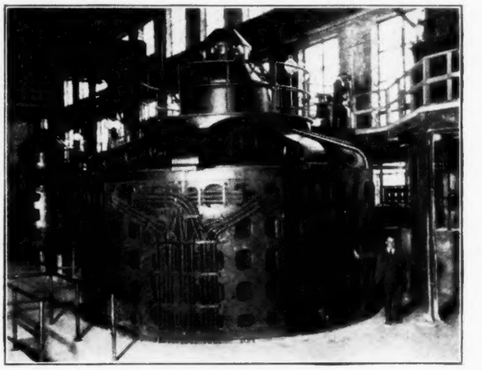
Each unit is capable of producing 37,500 H. P. at 12,000 volts, 3 phase, 25 cycles, and are so arranged and tied together that they can be controlled from one operating room by a single operator. The electrical characteristic of these machines, also, are so nearly alike that they can be tied together in parallel. In order to get the proper inductive balance, this electrical paralleling is done several miles from the power house. The water is taken from the canal, as in the case of the installation previously described, passes through control gates, down a sloping penstock to the turbines situated just above the level of the river below the falls. The power house in which these units are installed is adjacent to that previously described as developing 130,000 H. P. The turbines in this latest development have vertical shaft, and take the water around the periphery of the wheel or runner and discharge it down from the center. The design of the blades of the rotating wheel, and the shape of the approach and discharge, have been so carefully considered that as a result over 93 per cent of the energy of the water is transmitted to the vertical shaft, and the water emerges from the discharge outlet with no commotion and just sufficient velocity to carry it away from the turbines. The units are kept at constant speed regardless of load by means of governors which control the amount of water flowing into the turbines. This control is effected by 20 swinging guide vanes situated around the circumference of the runner. These vanes are operated by means of a ring which in turn is actuated by pistons in large cylinders. The displacement of these pistons is controlled by the governor which admits fluid at a pressure of 115 pounds, or discharges it into a sump tank as required. The governors are so delicately balanced and adjusted that the water flow into the turbine will be shut off in three seconds if the load on the generator fails. Originally oil was used as the actuating medium in these pistons, but, as it is almost impossible to prevent leakage, not only was a large amount of oil wasted but the compartment where the gates were installed soon became slimy and unsightly.

This condition is obviated by using a mixture of soluble oil and water in place of oil alone. It was found that a 1 per cent mixture of soluble oil in water was sufficient to furnish adequate lubrication to the moving parts and prevent rusting and corrosion of the metal. The cost due to leakage is thus reduced to a very small amount, and such liquid as does leak out, on account of its soluble nature, easily washes away with water and leaves the compartment clean. The shafts of the guide vanes are lubricated by means of grease guns in such manner that definite quantities of grease are furnished to them.

The runner, which actually transforms the energy of the water into torque in the main vertical shaft, is cast in one piece and has a diameter of 10½ feet. The shaft, 29 inches in diameter, is provided with two guide bearings, one directly above the runner and the other above the generator. On account of the water conditions, the lower bearing is constructed of lignum vitae with end grain to the journal, and is lubricated with water under pressure from the top of the penstock. The upper guide bearing is babbitted and lubricated with oil.

In order to furnish a means for completely shutting off the water from the turbines, not only are gate valves installed at the top of the penstock, but a giant needle valve is placed in the penstock near the entrance to the turbine. This needle valve, though weighing 100 tons with a moving piston weighing 26 tons, is so balanced and controlled by water pressure that it can be operated by a small electric switch on the main control board, and can be made to

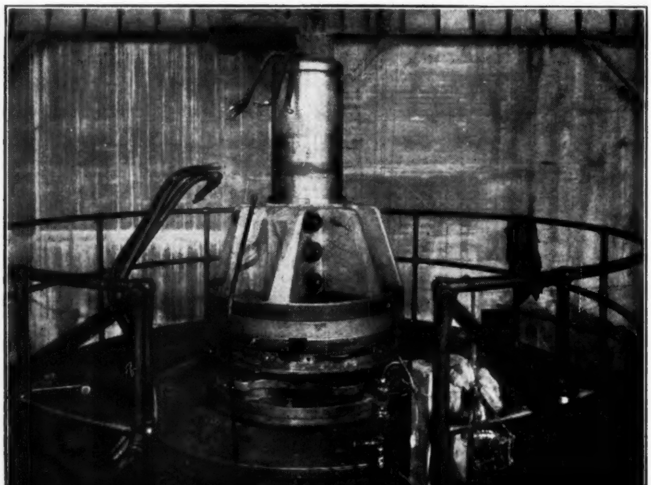




View of latest type vertical units in Plant No. 3 extension. Turbines beneath the floor. Notice exciters, auxiliary control board and governors upon the platform. Oil storage reservoir is placed at the top of the room but not visible.

Close-up of generator of vertical units. Notice Kingsbury thrust bearing housing at the top. Glass windows allow observation of action of bearing.

Kingsbury bearing with casing removed. Notice rocking plates and stationary portion.



give any cross-sectional area desired for the admission of water.

The weight of the rotating portion of each of these units, runner, shaft, generator, rotor, etc., is carried on a Kingsbury thrust bearing. This bearing also must carry the downward thrust due to the water pressure which, together with dead weight, amounts to almost 250 tons. This bearing is 49 inches in diameter with six rocking plates. The upper portion of the bearing is attached to the shaft while the lower portion is supported by a spider which carries the load to the frame.

Lubrication System

In order to lubricate properly these large units, particular attention was paid to the design of the lubrication system. The thrust and upper guide bearings are supplied with oil by separate pipes leading from a storage tank of 2,000 gallons capacity in the upper part of the power house. This gravity head gives sufficient pressure to force the oil into the bearing; in fact the pressure is somewhat excessive, and a regulating valve and oil meter is installed in the thrust bearing line in order to keep the supply down to 35 gallons per minute. As an extra precaution against any extraneous dirt or pipe scale getting into the bearings, a duplex strainer with 50-mesh wire is installed in the feed line and so arranged that it can be cleaned without interrupting the flow of oil. After passing through the bearings the oil from all three of the sets runs to a common header and thence to the filtering system. This contains three filter tanks of 60 gallons per minute capacity connected together by equalizer pipes on both the dirty and clean oil sides so as to practically act as one filter. The oil rises in the used oil compartment containing the filtering units until the level is sufficiently above the outlet pipes from the filtering units to force it through the filter cloths. An oil gauge on the side of this compartment shows the level of the oil and also acts as an indicator to tell when the cloths are dirty, as a dirty cloth requires greater head to drive the oil through it at the required speed than a clean one. After passing through the cloths, the oil is passed in a zig-zag fashion over cooling coils into the clean oil compartment below. Each filter tank has a cooling surface of 120 square feet and a clean oil storage of 2,000 gallons. Each filtering compartment contains thirty-four 18″ × 36″ filtering units, giving a total filtering surface of 306 square feet for each of the three filters. Each filtering unit is so constructed that it can be removed, cleaned, and replaced without disturbing the other units in the compartment.

The oil from the clean oil compartments of the three filters is elevated to the gravity tank by means of a motor-driven single-stage centrifugal pump of 120 gallons a minute capacity. A second pump of equal size is connected in parallel and is used as a spare. These pumps operate automatically, being controlled by floats in the oil compartments, so that proper supply is kept in the overhead tank. A battery of gauges indicate the level of oil in the various tanks, and an alarm is sounded if the oil level becomes too high or too low.

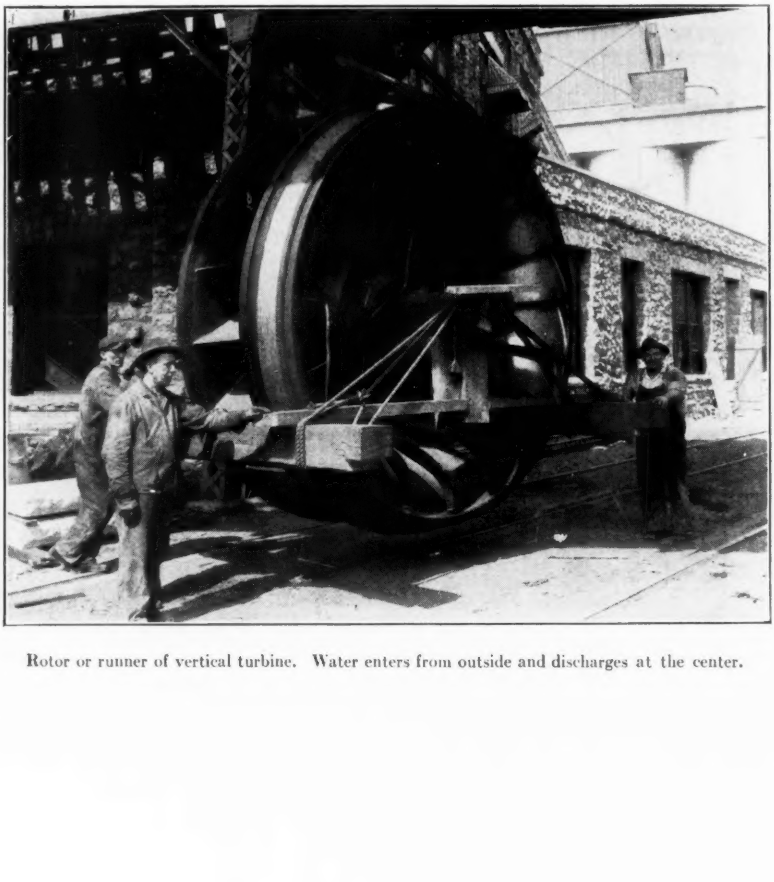
An oil of 180 seconds viscosity, at 100° F. Saybolt universal, has been found to operate very satisfactorily in these bearings, but it must be well refined, filtered, and otherwise treated so as to be non-emulsifying with water and not break down on continual use. The oil and bearings have been so thoroughly developed that the oil emerging from the thrust bearing shows a rise in temperature at full load of only 6° F., and the loss in power due to bearing friction is only 26 H. P. or 7/100 of one per cent of the power of the unit.

The large electric generators are excited by means of induction motor generator sets, driving D. C. generators of 225 K. W. capacity, and furnishing current at 220 volts. These exciters are so tied up and cross connected through control switches that they can be operated from different sources of current supply as expediency may demand.

In addition to the excitors there are other auxiliary apparatus that require efficient lubrication such as pumps, air compressors, small motors, etc. Air compressors are perhaps the most exacting of these in the matter of the proper lubricant to give the most satisfactory and continuous service. As this subject was

treated quite completely in the June, 1920, issue of LUBRICATION, the reader is referred to that number. In regard to pumps, small motors, etc., the principal factor in correct lubrication is care in selecting a system that will furnish high grade lubricants continuously so that the plant will not shut down due to the failure of a small, but very important, feature in its operation.

We have described in the foregoing one of the most modern plants transforming hydraulic energy into electric power. This is done at a very high efficiency with little loss of available energy, and is particularly noticeable in the case of the last units installed. This is shown by reference to the general view picture. The latest plant is shown on the right and, although the units are working full capacity, there is scarcely any commotion in the water emitted from the turbines. No small part of this efficiency is produced by the correct lubrication of the units, and, when it is considered that only 7/100 of one per cent of the power is lost in friction of the units, it shows that the lubrication engineer is doing his part in preventing energy going to waste. The hydraulic engineer is still slightly behind but going strong. The methods used in this plant can be adapted to other hydro-electric plants by the use of proper high-grade lubricants and a system of application of the lubricants that assure them of being used in such manner as to obtain their full value. This cannot be done by haphazard design, but only by a correct application of lubrication data that has been accumulated after long and broad experience.



Rotor or runner of vertical turbine. Water enters from outside and discharges at the center.

Flash and Fire Tests, Their Importance

Standard Instruments for Testing and Methods of Operation

Practically all substances with which we are familiar, occurring naturally in one of the three states in which all matter is classified, may, under favorable conditions of temperature, pressure, etc., be changed from a solid to a liquid and thence to a vapor; and, in most instances, the transformation may be completely reversed. The amount of such alteration is in general dependent upon the severity of changes from the normal environment. For example, we are accustomed to think of lead, paraffine wax, and asphalt as solids; of water and oils, as liquids; of air and carbonic acid, as vapors or gases. It is found, however, that changes of temperature and pressure of sufficient magnitude will entirely modify these substances from their normal state. For example, solids such as lead, paraffine wax, or asphalt will, upon sufficient heating, assume a liquid state. By still further heating of the liquid, they may be caused to vaporize or volatilize. The ease with which the change of state is brought about is dependent upon certain inherent physical properties of the individual substances.

When oil is heated it will give off vapor, the amount of heat necessary to bring this about being influenced largely by the nature or complexity of the oil itself.

Not all substances when heated to the vaporizing point yield an inflammable gas, but this characteristic is found in oils and allied substances, and the temperature at which an oil, upon heating, in the presence of air develops vapors, which, upon the application of a spark or small flame, will ignite or flash, is called the "flash point." When the heating is continued above the flash point, a temperature is reached where the vapors are thrown off the surface of the oil in such quantity as to ignite and burn continuously. The recorded temperature at which this occurs is called the "fire point."

According to Technical Paper 49, Petroleum Technology 10, Bureau of Mines, on "The Flash Point of Oils," from which the following is quoted: "Flash point is not an indication of the value of an oil for any particular purpose. It is an indication only of the temperature at which oil gives off vapor in such proportion that they form an inflammable mixture with the air." The purpose of the flash test, no doubt, has always been to determine the fire or explosion hazards of oils, and according to this same article, "the flash point, although probably the most important factor, will not by itself determine the fire hazard of any substance. The fire hazard of a substance is also affected by the volatility, the boiling point, the vapor pressure, the vapor density, the diffusibility and tendency of the vapors to travel and their explosive limits in air, its tendency to chemical change, the quantity of heat liberated per unit of time and unit of volume, the temperature of the flame, the corrosive action and toxic properties of the substance and of its products of combustion, its behavior toward water both before and after ignition, and the tendency of the substance to leak.

"A requirement that an oil have the highest practicable flash point, tending thereby to reduce the fire hazard to a minimum, is praiseworthy and humane. To require too high a flash point may impair the burning qualities of a lamp oil and also work a hardship on the refiner. However, the immediate profits of the refiner should be deemed less important than the safety of the user and the protection of the public against possible loss of life and of property by fire.

"The fire hazard of lubricating oils is of importance when the lubricants are used in rapidly running machinery, as in spinning mills, wood mills, etc., or are used in factories containing combustibles and in compressors for air, ammonia, or other gases."

The importance of being able to estimate with some degree of accuracy the point at which a substance, when heated, will produce vapors of an explosive or inflammable nature has been recognized for a great many years. In 1862, Great Britain took some governmental action

with an idea of obtaining an instrument and method for the determination of flash and fire points. No doubt, the object in view was to provide greater safety to the miners by prescribing a minimum temperature of flash point of lamp oils used in the mines, for lamp oils or illuminating oils were then coming into very extensive use for lighting purposes in the industries as well as in the homes. In 1868, an instrument similar in principle to that of our present day open cup tester was brought forth. It did not, however, arouse much interest and it was not until 1875 that the Abel-Pensky Tester was proposed. The Abel-Pensky instrument of to-day is only a slight modification of the original Abel model.

The legion types of instruments that have been developed or invented since 1875 have principles of design and operation which are more or less in common. The instruments constructed for the purpose are divided into two classes, namely, the "open cup type" and the "closed cup type." In the former, the cup or vessel containing the sample of oil is uncovered, while in the second type it is covered while the experiment is in progress.

The enactment of laws controlling limits of flash point tolerance no doubt became necessary both in international and interstate commerce through enormous increases in the use of petroleum oils, especially kerosene. The nations of the world as well as the several states in our own land have established some flash instrument as a standard.

For domestic and industrial purposes a considerable degree of safety to lives and property had to be provided. Before the advent of the gasoline automobile, which has drawn so heavily upon the petroleum resources, there is no doubt that the kerosene which was refined and sold carried a much greater proportion of low boiling constituents possessing greater inflammability and therefore more prone to flash or explode than material of the same sort to-day.

Types of Instruments

The flash point question grew to further importance through the transportation of huge quantities of petroleum oil in tank steamers, and also in the application of fuel oil for power purposes to replace coal in operations on both land and sea. The flash test instruments which have received most recognition are as follows:

1. *a.* Abel Closed Cup Tester
   b. Abel-Pensky Closed Cup Tester
2. Pensky-Martin Closed Cup Tester
3. Tagliabue Closed Cup Tester
4. Foster Automatic Closed Cup Tester
5. Luchaire Closed Cup Tester
6. Granier Closed Cup Tester
7. "TAG" Closed Cup Tester
8. Elliott (New York State) Closed Cup Tester
9. Treumann (German Railways) Open Cup Tester
10. Tagliabue Open Cup Tester
11. Cleveland Open Cup Tester

Of these, some are still recognized as standard instruments in this country and abroad, for example, the Granier (the first automatic tester introduced) has been used officially in France for many years. In many countries, the Abel or Abel-Pensky model is the authorized instrument for test. Practically all of them have been used as a basis for legally allowable flash point minima for petroleum oils of commerce. Some have become obsolete, or at least, not frequently referred to in practice. The requirements of many of our states still call for flash point readings according to the Abel, Abel-Pensky, or Tagliabue Closed Cup Testers. The last, however, has practically been supplanted by a new device known as the "TAG" Closed Cup Tester. Its use has already been prescribed by the American Society for Testing Materials.

The Abel-Pensky instrument has a rather wide range of application. It is admirably adapted to the testing of such articles as comparatively low flash point solvent naphthas, mineral spirits, or so-called turpentine substitutes and kerosene.

The Pensky-Martin instrument is used principally in the determination for flash point of fuel oils and crudes. It is in general used upon oils having a flash test not above 250° F.

The Tagliabue Closed Cup Tester is used principally for the more volatile substances such as the mineral spirits and kerosene.

The Foster Automatic Closed Cup Tester is intended strictly for the illuminating oils.

The Luchaire and Granier Closed Cup Testers are used over a very wide range of flash points.

The "TAG" Closed Tester finds particular applicability in the testing of materials having flash points not in excess of about 175° F.

The Elliott (New York State) Closed Cup Tester finds use in the testing of a rather large variety of petroleum oils. For low flash material a water bath is used to heat the oil undergoing test. For materials flashing above approximately 175° F., the water bath is replaced by oil of high flash, such as linseed. In this manner, road oils and asphalts may be tested.

The Treumann Open Cup Tester is used in determining the flash point of mineral lubricating oils in use on the German State Railways.

Probably the most widely used instrument for testing lubricating oils of all description is the Cleveland Open Cup Tester. It has wider distribution throughout the United States than any other instrument of like purpose. All laboratories devoted to oil inspection are always provided with one or more of them. Nearly all lubricating engineers are thoroughly conversant with the instrument and the manner of operating it.

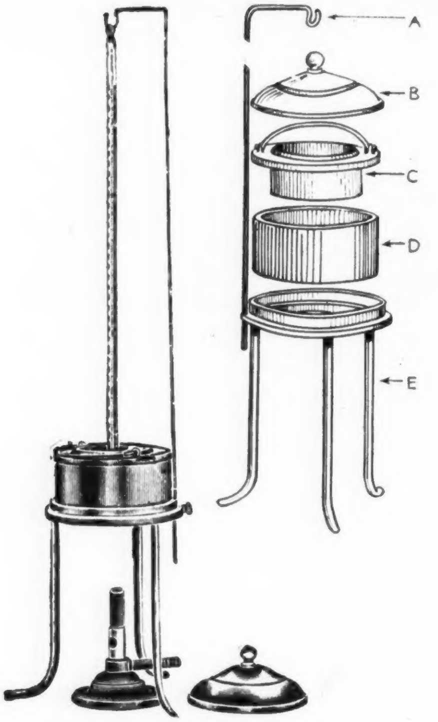
But few realize the great number of factors influencing all flash point work. Some are prone to attribute to lubricating oils of relatively high flash point, better lubricating qualities than oils of lower flash point. It may be emphatically stated that flash point is not a measure of lubricating qualities; it only serves as a physical index of the temperature at which the oil, if heated, will throw off vapors which, upon admixture with air, will flash or ignite. Therefore, it is a question remote from that of lubrication.

Influencing Factors

Referring again to the Technical Paper No. 49, by Dr. Dean of the Bureau of Mines, one finds a list of factors which have influence upon the determination of flash point.

"First of all, the conditions under which flash testing is done should always be comparable. Tests should always be repeated and using fresh samples of the oil.

2. On account of the influence of barometric pressure on flash point, final observations should be corrected for barometric pressure using a proper correction table. A rise of 1 mm. in the barometer effects a rise in flash point of about 0.038° C.
3. The shape and size of the cup in which the oil is heated is of importance. The dimensions of the oil cup in the Cleveland tester are practically standard.
4. Size of thermometer bulb has to be taken into consideration in testing for flash point. It is customary to prescribe the kind of thermometer to be used in the instrument.
5. In taking flash and fire tests, the operator should always be governed by some standard method so that the work he does may be at all times comparable. The rate of heating should always be confined to relatively narrow limitations, for it has been definitely proved that a particular oil, when heated at a given rate, will show a different reading if the rate of heating is more rapid or reduced in rapidity from the standard rate. An oil which has been heated more rapidly than the specified rate will, as a rule, show a lower flash point reading. When a longer time than specified is allowed to bring the temperature of the oil up to the flash point, the reading of flash point is, in general, higher.
6. The size of the test flame should always be constant. A large test flame generally brings about a lowering of the flash point.
7. The test flame should never be applied to an oil more frequently than the directions for operating the instrument demand. Repeated application of the test flame will bring about a destruction of the vapors without producing the actual flash.
8. Samples of oil containing water in the form of an emulsion or otherwise should be previously heated to a point below the expected flash point and allow the water to settle out. Only an oil practically free from water should ever be placed in the flash test cup on account of the danger of foaming and frothing which will frequently cause the cup to over-flow. The presence of water vapor makes the determination of flash point very uncertain, and the presence of 1 per cent of water will prevent flashing entirely. Even smaller quantities will bring about increases in temperature at which the flash point is observed.
9. The efficiency and accuracy of a flash cup apparatus is, to a large degree, commensurate with the extent to which personal equation is eliminated. The most satisfactory instrument for the purpose of flash point testing is one whose manipulation is made entirely mechanical and automatic."



A. Thermometer supporting rod. *B*. Cover. *C*. Oil cup. *D*. Bath cup. *E*. Tripod.

Method of Tests

Above is a cut of the Cleveland Open Cup Tester. The following standard method of test is suggested to those who have occasion to examine lubricating oils for flash point:

1. Have the cup clean and dry, and comparatively cool.
2. Place the cup in the metal air bath, being sure that the cup is resting evenly in the bath and is level.
3. Pour the oil to be tested into the cup, filling the cup to one-fourth inch from the top.
4. Suspend thermometer in the oil so that the top of the bulb is just under the surface of the oil.
5. Regulate the fire under the bath so that the temperature of the oil rises at a uniform rate of 7° F. per minute. An oil with a high flash point can be heated more rapidly at first, but should be at the proper rate for 40° F. before the point of flash.
6. When about 30° F. from supposed point of flash the flash test shall be made by bringing the taper close to the surface of the oil at three or four points near the outside edge of the bowl. The flash test shall be made on the zero and five degree points and shall be repeated every five degrees elevation in temperature on the thermometer. The point at which the flame leaves the taper and goes to the surface of the oil shall be called the flash test or flash point of the oil.
7. Continue to test for flash every 5° F., testing on the multiple of 5, until the first flicker of blue flame appears on the surface of the oil. This is the flash point.
8. Record your results.
9. Continue to heat the sample at the same rate and test every 5° rise for the fire test. In testing for the fire test, apply the test flame and remove it as quickly as possible, in order to burn off the accumulated gases without holding the flame longer than necessary. When the flame persists and the oil burns for five seconds you have the fire test.
10. Remove your thermometer and extinguish the fire by covering it with the metal cover.
11. Record the results.

NOTE: *Flash and fire tests must not be taken in strong light, or where there is any draught.*

In the foregoing we have indicated the significance of Flash and Fire Points and the usual methods of determining them. In the case of burning oils the principles underlying these determinations are quite important, and much work has been done on the design of apparatus that will give definite and consistent results and eliminate the personal equation of the operator. These all, however, fall short of giving a physical constant that definitely determines any property of the oil which cannot be determined more accurately in some other manner, as by evaporation or distillation tests. As a means of making a rapid determination of comparative tendencies of oils to give off vapors at certain temperatures, which will readily produce explosive mixtures, flash and fire point determinations are still useful provided apparatus and methods of procedure are standardized.

In the case of lubricating oils, however, flash and fire points have practically no value in indicating lubricating qualities. The flash and fire points of lubricating oils are all sufficiently high as to show that there is practically no fire hazard and even in special cases where these determinations might give indications of constituents of too low boiling points, these can be determined much more accurately and satisfactorily by evaporation and distillation tests. Where specifications still demand that flash and fire points of lubricating oils be taken, the Cleveland Apparatus is perhaps the most satisfactory standard to use for t[illegible] purpose.

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Lubrication

A Technical Publication Devoted to the Selection and Use of Lubricants

Lubrication of Pulp and Paper Mill Machinery

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